Bioeconomics: a bibliometric analysis in Latin America and the Caribbean

Bioeconomía: análisis bibliométrico en América Latina y el Caribe

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Abstract

This article offers a vision of how Latin America and the Caribbean (LAC) have adopted the principles of the bioeconomy in the last two decades with different levels of socio-economic impact. The analysis was carried out with 706 publications obtained from the SCOPUS database between 2003-2020. The results allowed us to identify that in LAC, there are capacities for the development of the bioeconomy; however, these potentialities are disparate at the

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country level. It was identified that the three countries that most promote the development of this issue are Brazil, Argentina, and Mexico. The structural analysis of the bioeconomy work showed a high rate of cooperation between LAC institutions with institutions in North America, Asia, and Europe. The relevance of the bioeconomy in LAC is highlighted as an alternative for growth with emissions decoupling, contributing to productive diversification, especially in the agricultural and agro-industrial sectors. The potential of (agro) biodiversity resources, the capacity to produce biomass for various uses, in addition to food, and the availability of agricultural and agro-industrial waste are highlighted. This research aimed to analyze the bioeconomy in LAC from a bibliometrics perspective to explore scientific studies related to the concept.

Keywords: *Bioeconomy, Latin America and the Caribbean, Bibliometric analysis*

Resumen

Este artículo ofrece una visión sobre cómo América Latina y el Caribe (LAC) ha adoptado los principios de la bioeconomía en las últimas dos décadas con diferentes niveles de impacto socioeconómico. El análisis se realizó con 706 publicaciones obtenidas de la base de datos SCOPUS entre 2003-2020. Los resultados permitieron identificar que en LAC existen capacidades para el desarrollo de la bioeconomía, sin embargo, estas potencialidades son dispares a nivel de los países. Se identificó que los tres países que más impulsan el desarrollo de este tema son Brasil, Argentina, y México. El análisis estructural del trabajo en bioeconomía mostró que existe una alta tasa de cooperación entre instituciones de LAC con instituciones en Norte América, Asia y Europa. Se destaca la pertinencia de la bioeconomía en LAC, como alternativa para un crecimiento con desacople de emisiones, que contribuya a la diversificación productiva, especialmente en los sectores agrícola y agroindustrial. Se subraya el potencial de los recursos de la (agro) biodiversidad, la capacidad para producir biomasa para diversos usos, además de alimentos, y la disponibilidad de desechos agrícolas y agroindustriales. Esta investigación tuvo como objetivo el análisis de la bioeconomía en LAC desde una visión de la bibliometría con la exploración de los estudios científicos relacionados con el concepto.

Palabras clave: *Bioeconomía, América latina y el Caribe, Análisis bibliométrico*.

1. Introduction

The European Commission coined the term Knowledge-Based Bioeconomy (KBBE) to transform knowledge of the life sciences into new, sustainable, eco-efficient, and competitive products (Aguilar, Bochereau, & Matthiessen, 2009). In other words, these processes must produce "more with less," thanks to the performance of living beings. Thus, the use of biomass to produce biofuels in "biorefineries" or of microbial enzymes in various food and textile industries or value chains that include, in addition to useful products, the recycling of waste and by-products, are examples of bioeconomy that are based on new advances in the biological sciences. LAC has abundant fossil, mineral, and biological resources, which have shaped its economy for centuries. In turn, the demographic challenges of the 21st century and industrial transformation generate new value chains and economic models that have driven initiatives for bioeconomic solutions in the region. The term "bioeconomy" encompasses the traditional economy, all industrial and economic sectors that produce and manage biological resources and related services. However, it performs exploitation differently by establishing the production processes of new chains of value sustainably. The more excellent knowledge in life sciences has resulted in promoting the substitution of fossil fuels and materials derived from fossils by materials derived from biodiversity, thus minimizing environmental impact and recycling waste towards more sustainable development. In this sense, the Latin American bioeconomy has focused on aspects such as:

-Achieve the sustainable use of biodiversity.
-Achieve the eco-intensification of agriculture,
-Implement biotechnology applications in the mining industry,

-Establish biotechnological applications applied to the food and beverage industries,
-Implement biorefineries for the use of agricultural by-products,
-Establish a bioeconomy that is aware of ecosystem services.

On the subject of sustainable uses of biodiversity, plant products play an essential role in health systems. For example, medicines extracted from plants represent around 25% of the prescriptions filled in the US. The World Health Organization estimates that around 80% of the world's inhabitants still depend on traditional medicine, including plant extracts and phytochemicals, for primary health care (2002). LAC has excellent plant biological diversity and has depended on plant-based medicine for centuries. In this sense, the best-documented initiatives correspond to work carried out by INBio (National Institute of Biodiversity of Costa Rica), whose strategy has been to develop agreements for bioprospecting, training, and capacity building with different companies and countries. The other important example is the collaboration between Peru and South Korea: the agreement was signed between KRIBB (Korea Research Institute of Bioscience & BioTechnology) and the Peruvian Council of Science and Technology (CONCYTEC), aimed at the evaluation of 450 medicinal plants from the Amazon rainforest. Other initiatives in the region have not delivered on their promise, mainly due to the lack of applicable legislation and stakeholder reward schemes (Sasson & Malpica, 2018). Regarding the issue of ecointensification of agriculture, an example to highlight is the organization of Argentine agriculture and livestock, which have gradually evolved to a point where both the rural company and the sector as a whole have become very different from what they were a few decades before. Production and innovation groups were formed, and relationships were established beyond commercial exchanges governed solely by prices. The groups mentioned above have promoted the development of technical and organizational capacities that depend not only on individual productivity but also on the exchange links between the various actors involved in the activities (Bisang, 2008). Argentina, in this sense, is making rapid progress on issues aimed at this achievement, such as work on genetically modified crops, collaborative work between farmers and companies in the agricultural sector, and the development of new strategies for working the land to improve their productivity (Sasson & Malpica, 2018). For its part, Brazil through EMBRAPA (Empresa Brasileira de Pesquisas Agropecuarias, Portuguese acronym for the Brazilian Agricultural Research Corporation), has developed varieties of transgenic crops, which not only meet the needs of its farmers but also lead to a strong economy in the production and trade of commodities.

Finally, another tool that is worth mentioning, which contributes to the real bioeconomy, is digital agriculture, which corresponds to the use of a variety of technologies, for example, drones or near and remote sensors, use of Internet technologies from Things (IoT) to make decisions on when to start harvesting crops, remote disease management, changing weather conditions, in this way digital agriculture can make a real contribution to the development of an effective bioeconomy. Environmental biotechnology, also called "white biotechnology", includes all biotic processes aimed at controlling pollution, e.g. Eg treatment of wastewater, industrial effluents, and solid waste. This environmental biotechnology contributes to a green economy and, indirectly, to a bioeconomy, through the reuse and recycling waste. A good example in Latin America is the outstanding effort made by Chile (the world's third-largest copper producer) in the application of bioleaching (or biometallurgy) to extract copper. Nutraceuticals, also called the functional food sector, is a relevant area for the development of the bioeconomy in LAC. The Andean countries and that include Amazonian ecosystems offer numerous examples of plant and wild species which are and could be exploited as functional foods if clinical tests are carried out on the use of their relevant organs (roots, fruits, seeds, and leaves) and if they are they can be grown on a commercial scale, once, for those with possibility, their nutraceutical value has been scientifically proven. First-generation biofuels or agrofuels, such as ethanol from corn (starch) and sugarcane (sucrose), and biodiesel from vegetable oils (palm oil and rapeseed), are now established in many countries, often encouraged by generous subsidies and supporting regulations (Parker, 2011).

Brazil, the world's second-largest ethanol producer, behind the United States, and the leading exporter, produces its fuel mainly from the fermentation of sugar cane. Processing plants can go back and forth between ethanol and crystallized sugar, depending on prices. They can even be converted into "biorefineries" where fuel or sugar is produced and other types of products, using bagasse as an energy source for these refineries. Likewise, since 2006, Clayuca Corporation (http://www.clayuca.org/sitio/index.php/procesamiento/produccion-de-ettanol), has developed an exciting example of how to leave monoculture for the production of bioethanol, in which several Latin American countries participate, using cassava, sweet potato, and sweet sorghum as raw materials. Ecosystem functions are the chemical, physical and biological processes that contribute to the self-maintenance of the ecosystem. Some examples of ecosystem functions are the provision of habitat for wildlife, the carbon cycle, or the capture of nutrients. Thus, ecosystems, such as wetlands, forests, or estuaries, can be characterized by the processes that occur within them. Some examples of ecosystem services support the food chain, sustainable collection of animals or plants, and the provision of clean water or exceptional landscapes. These can be calculated in the form of natural capital variation in forests, land, and water and their potential benefits, how they are produced, and what social development growth objective they support can also be calculated (https: //seea.un.org /). Understanding the importance of ecosystem services and taking them into account when building new value chains is critical to bioeconomy initiatives' success.

To conclude this document, this document's objective is to present a current bibliometric analysis of research work on the bioeconomy issue at the LAC level and thus establish a baseline of trends in this area at the local level.

2. Materials and methods

The previous research is part of a retrospective, and descriptive study carried out through Scopus ((https://www.scopus.com/home.uri), a database that provides information on citations for more than 25,000 active titles, such as journals, conference proceedings, and books. It was considered to use this database and not Web of Science (WoS)) (https://mjl.clarivate.com/) despite being considered one of the most complete, since Scopus showed a more significant number of documents than (Wos). The search was carried out on July 29, 2020, by providing the keyword "Bioeconomy" with an enabled time interval of "Every year". An article on bioeconomy was considered to be from LAC when at least one of the affiliated authors belonged to one of the following countries: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Ecuador, El Salvador, Guyana French, Grenada, Guatemala, Guiana, Haiti, Honduras,

Jamaica, Mexico Nicaragua, Paraguay, Panama, Peru, Puerto Rico, Dominican Republic, Suriname, Uruguay, Venezuela. For this, the filter option (country/territory) of the database was used. With this search strategy, the database provided different types of documents since 2003, and everything published in progress for the year 2020, as shown in Table 1.

Table 1. *Types of documents analyzed and percentage distribution in the period 2003-2020*

Types of documents	Number	%
Article	494	69,97
Book	1	0,14
Book Chapter	66	9,35
Conference Paper	19	2,69
Editorial	6	0,85
Erratum	1	0,14
Note	2	0,28
Review	115	16,29
Short Survey	2	0,28
Total	706	100

Analysis programs

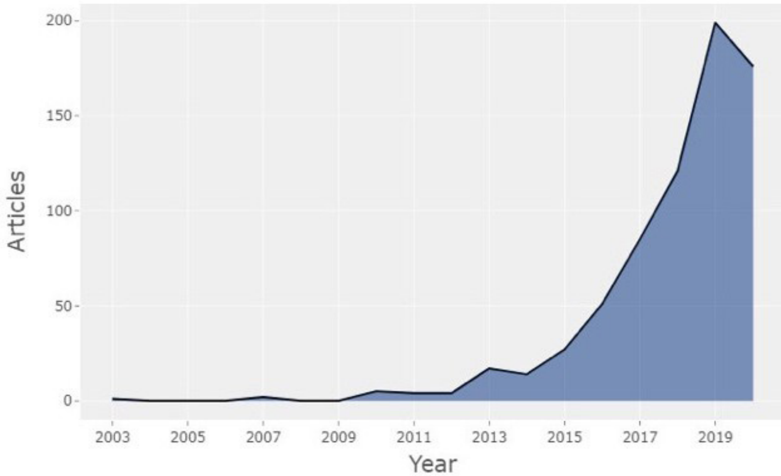
The bibliometrix R package (http://www.bibliometrix.org) provides a set of tools for quantitative research in bibliometrics and scientometrics. This program is written in the R language, which is an open-source environment and ecosystem. The existence of powerful and effective statistical algorithms, access to high-quality numerical routines, and integrated data visualization tools are perhaps essential qualities that distinguish R from other languages for scientific computing (Aria & Cuccurullo, 2017). The data retrieved from Scopus was analyzed using R studio v.1.1.456, R v.3.5.1 (2018-07-02), and bibliometrix R-package (http://www.bibliometrix.org) (Aria & Cuccurullo, 2019). The generation of graphics was carried out using the biblioshiny application. Additionally, data mapping was carried out according to the study theme, using the VOS (Visualization of Similarity) visualization program (Van Eck and Waltman 2010, 2014b; www.vosviewer.com), to demonstrate the scientific panorama, especially complex geometric scientific relationships such as co-citation and coword occurrence analyzes in Bioeconomy research.

3. Results and discussion

Annual Scientific Production

The annual trends of scientific production in terms of publications are represented in Figure 1. The production results reported in the Scopus database used are shown, from 2003 to July 29, 2020. The number of publications' growth was not very noticeable in the years from the start date of the study to 2012. However, as of 2013, there is a considerable increase in the number of publications, from 17 to 189 in 2019, and in what analyzed in 2020, 176 documents were found.

Figure 1. *Annual Scientific Production of bioeconomy in LAC*

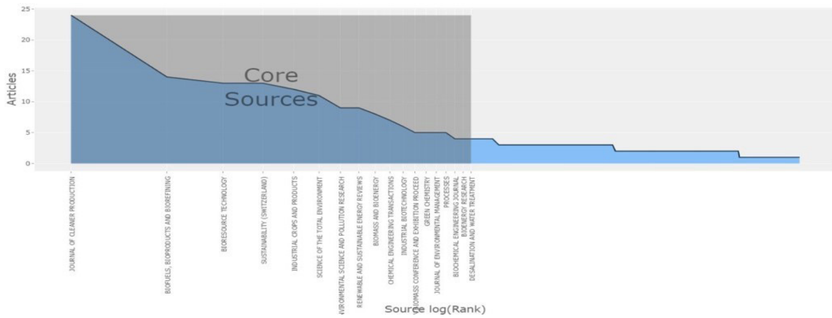


The analysis in the established period showed an annual growth rate equivalent to 53.86%. It is possible to affirm that the growth in the production of this topic is related to the interests that countries have presented in recent years to promote the bio-economy (Konstantinis, Rozakis, Maria, & Shu, 2018)

The 25 most productive fonts showcased with publications

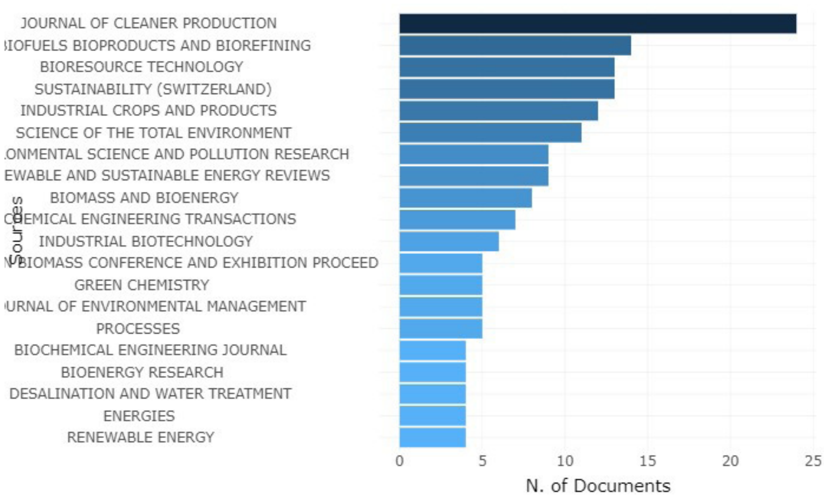
Figure 2 shows the journals that consolidate the core of knowledge, with the highest number of publications, on the subject of Bioeconomy as established by Bradford's Law. This shows an unequal distribution, that is; that most of the articles are concentrated in a small group of journals, while another portion of articles is dispersed in a high number of these (Urbizagástegui Alvarado, 2016).

Figure 2. *Representation of Bradford's law for the term Bioeconomy, for Latin America, concerning the bibliographic sources with the highest number of publications*



It was found that the Journal of Cleaner Production with a Q1 rating stands out for being the journal with the highest number of publications with a total of 24. It is followed by the journal Biofuels Bioproducts and Biorefining with 14 publications and is also located in the quartile Q1 (Figure 3).

Figure 3. *The 25 most productive sources displayed with publications*



Author productivity in terms of h-index, g-index, Total Citations (TC), and Total Publications (TP)

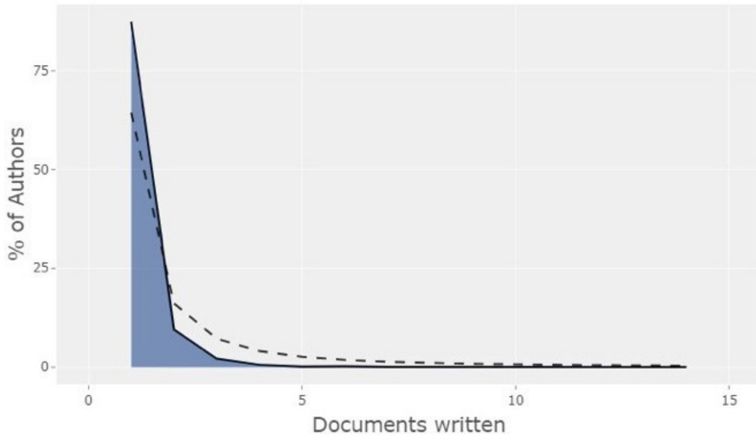
The h index is an author-level matrix that defines the number of documents that have been cited by a given number. This index is a reliable and authentic tool for mapping the scientific contribution achieved by an individual author (Hirsch, 2005). For its part, the g index is also calculated from the distribution of citations received by a specific researcher's publications. It is similar to the h-index, more involved in its calculation, but being more extensive and more variable allows us to distinguish between authors with a similar h-index (Egghe, 2006). Table 2 shows the 20 principal authors and their level of productivity based on the following parameters: total number of publications (NP), the total number of citations (TC), H and G indices in bioeconomy research at the level of LAC and the relationship between the number of authors and the number of publications generated on the subject. It should be noted that the authors with the highest h and g index values are Maciel Filho, Rodríguez, Carrilho and Labuto assigned to institutions in Brazil and Argentina: School of Chemical Engineering, University of Campinas (UNICAMP), Campinas, Brazil; Department of Chemistry, Universidade Federal de São Paulo (Unifesp), Diadema, Brazil; Institute of Biodiversity, Experimental and Applied Biology, University of Buenos Aires, Argentina; Department of Science of Nature, Mathematics and Education, Universidade Federal de São Carlos, Araras, Brazil respectively.

Table 2. *The 20 authors with the highest bioeconomy productivity in Latin America*

Author	h_index	g_index	TC	NP
Jacob Lopes E	x3	5	33	14
Zepka Lq	3	5	30	12
Chandel Ak	3	9	101	9
Dos Santos Am	2	4	24	6
Klingen I	2	4	19	8
Maciel Filho R	5	8	110	8
Mussatto Si	4	8	107	8
Rodrguez Em	6	7	55	8
Freire Dmg	4	7	71	7
Venus J	3	5	30	7
Canosa Is	4	6	39	6
Carrilho Envm	5	6	36	6
Costa J	3	6	39	6
Da Silva Ss	4	6	131	6
Depr Mc	2	4	20	6
Farinas Cs	4	6	38	6
Fernando Al	3	6	39	6
Labuto G	5	6	36	6
Severo Ia	2	4	20	6
Arancibia F	3	5	57	5

Figure 4 shows that of Lotka's law, which describes the frequency of the authors' publications on the subject (Lotka, 1926). For the specific topic of bioeconomy in Latin America, it was found that most authors have few publications (4560 authors with 1 article each), and there is a lower percentage of authors with a higher level of production on the topic (1 an author with 14 articles).

Figure 4. *Relationship between the number of authors and written documents (Lotka's Law) for authors publishing in Bioeconomy, in Latin America*



Most cited country, article citations, and average citations obtained in bioeconomy publications

Table 3 shows the Latin American countries with the highest number of citations on the subject of bioeconomy. It can be seen that the Latin American countries that have the most citations are Brazil, Mexico, Argentina, Chile, and Colombia. In the first place is Brazil, with 1,445 citations (7.6 on average per article). Mexico has a total of 339 citations (6.11 on average per article). Another Latin American country with a presence in the publications on the Bioeconomy is Argentina, which up to the date of the study, had 236 citations with an average of 7.8 citations per article. Chile has publications on the subject with 156 citations in total, equivalent to an average number of citations per article of 11.14. In the last place, Colombia, with 55 citations and an average of 2.03 citations for each article. The results allow identifying that LAC has significant potential for the development of the bioeconomy worldwide. However, some countries in the region have extensive experience in applied research in biotechnology and innovative agricultural production techniques.

In contrast, others reflect a deficient scientific-technological development level, insufficient to maximize opportunities for research the emerging bioeconomy. These innovative experiences in leading countries in the region are supported by a solid base of biotechnological research applied to agro-livestock. A study financed by the Inter-American Development Bank (IDB) reflects strong growth in investment in regional research in agribusiness in the last decade, but with an intense concentration in Argentina, Brazil, and Mexico (Stads, Beintema, & Flaherty, 2016). Similarly, a study by the Inter-American Institute for Cooperation on Agriculture (IICA) reveals the dominance of various advanced biotechnology techniques in the region, such as in vitro cultivation of plant cells and tissues, in vitro reproduction, and cloning of animals. , plant transgenesis, genome sequencing, and bioinformatics, in this case, Argentina, Brazil, Colombia, and Mexico, show a degree of advance significantly higher than the average (Hodson, 2014).

Table 3. *The Latin American countries most cited in bioeconomy*

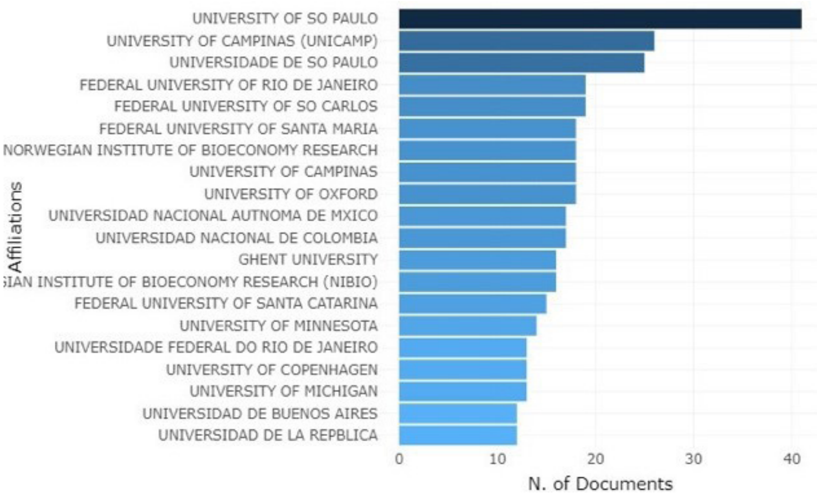
Country	Total	Average Citations per
Brazil	Citations1445	Article7,605
México	339	6,164
Argentina	236	7,867
Chile	156	11,143
Colombia	55	2,037
Guatemala	9	4,5
Costa Rica	8	8
Uruguay	7	1,75
Venezuela	7	7

Most relevant affiliation related to publications

The University of Sao Paulo is the university with the highest number of publications on the subject (32), followed by the University of Campiñas and the Federal University of Santa María (21 and 18 respectively), the three Brazilian institutions which supports the previous analysis about the Latin American country that has the highest productivity on the subject. Similarly, the graph shows the

University of Buenos Aires in Argentina, the National Autonomous University of Mexico, and the University of the Andes in Colombia among the most significant production on the subject. See Figure 5.

Figure 5. *The 20 most relevant institutions in the field of bioeconomy in Latin America*



Top 20 Authors' Countries

Table 4 presents the list of the leading Latin American countries of affiliation of the authors with the total number of articles, number of publications by a single country (SCP), the number of publications with the participation of multiple countries (MCP), and the relation between the number of publications with multiple countries and the total number of publications, (MCP_Ratio).

Table 4. *The main countries of the Latin American authors*

Country	Article	Frequency	SCP	MCP	MCP_Ratio
Brazil	190	0,42222	132	58	0,305
Mexico	55	0,12222	40	15	0,273
Argentina	30	0,06667	24	6	0,2
Colombia	27	0,06	20	7	0,259
Chile	14	0,03111	3	11	0,786
Uruguay	4	0,00889	3	1	0,25
Ecuador	3	0,00667	2	1	0,333
Guatemala	2	0,00444	2	0	0
Costa Rica	1	0,00222	0	1	1
Peru	1	0,00222	1	0	0
Venezuela	1	0,00222	1	0	0

According to the search criteria, the Latin American country with the highest number of publications on the subject is Brazil, with 27%, followed by Mexico with 8%, Argentina, and Colombia with 4%. When analyzing how publications are made, it is found that Brazil, as the leading Latin American country, has a total of 190 articles, of which 132 were developed only by Brazilian authors and 58 with authors from other countries. The preceding allows us to conclude that only 16% of Brazil's total articles were made in collaboration with other countries. In the second place, there is Mexico with 55 publications, of which only 15 were made in collaboration with authors from other countries. Argentina ranks third with a total of 30 publications, of which Argentine authors made 24. The previous shows that in these countries, there is no evident culture around collaborative work. Chile, contrary to the countries previously analyzed, despite having only 14 publications, is the Latin American country with the highest rate of collaboration, with 78.5% of the articles published.

The 20 most cited publications

Table 5 shows the list of the 20 most cited publications with their respective authors, year of publications, and journals in which they were published. For example, the publication was written by Jayasiri Sc entitled "The Faces of Fungi database: fungal names linked with morphology, phylogeny and human impacts" published in the journal Fungal Diversity in 2015, obtained the maximum of 361 citations in the period analyzed with a dating count of 60.1 per year. The participation of two Latin American authors linked to the Federal University in Viçosa, Viçosa, Brazil, and the University of Buenos Aires Argentina stands out. In the second position, we find the document published by Santos Jcsd entitled "Importance of the Support Properties for Immobilization or Purification of Enzymes" in 2015 with a count of citations equal to 45.8 per year. Colombian authors belonging to the following institutions, Universidad del Tolima and Universidad Industrial de Santander, participate in this document through their chemistry and microbiology programs, respectively.

Table 5. *The 20 most cited publications*

Paper	Total Citations	TC per Year
Jayasiri Sc, 2015, Fungal Diversity	361	60,167
Santos Jcsd, 2015, Chemcatchem	275	45,833
Roy He, 2016, Biol Invasions	150	30
Niederwieser D, 2016, Bone Marrow Transplant	140	28
Bender Rr, 2013, Agron J	133	16,625
Jacobs S, 2016, Ecosyst Serv	131	26,2
Buschmann Ah, 2017, Eur J Phycol	109	27,25
Arevalo-Gallegos A, 2017, Int J Biol Macromol	103	25,75
Brodin M, 2017, J Clean Prod	86	21,5
Chandel Ak, 2018, Bioresour Technol	85	28,333
Crago Cl, 2010, Energy Policy	79	7,182
Gupta Vk, 2016, Trends Biochem Sci	77	15,4
Carneiro Mlnm, 2017, Renewable Sustainable Energy Rev	72	18
Vaglio Laurin G, 2016, Remote Sens Environ	70	14
Blschl G, 2019, Hydrol Sci J	68	34
Ciriminna R, 2015, Biofuel Bioprod Biorefining	68	11,333
Nascimento Dm, 2018, Green Chem	63	21
Lupi L, 2015, Sci Total Environ	60	10
Pinho Adr, 2017, Fuel	58	14,5
Bilal M, 2018, Sci Total Environ	52	17,333

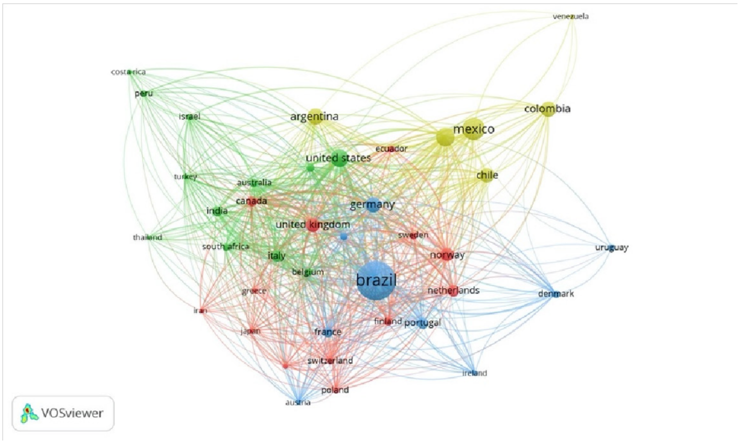
Structural Analysis and Visualization in Research Publications in Bioeconomics

Co-authorship analysis based on the countries that publish on the topic of bioeconomy in LAC

The LAC co-authorship network has been created using VOSviewer software (see figures 6 and 7). In the figures, a node symbolizes a country, while the node's size represents the country's activity. The curved line between the two nations shows the publication collaboration relationship between them. Finally, the thickness of the line shows the degree of collaboration between the respective countries. For this analysis, criteria were established, taking only for the study of those with at least 5 publications and 0 citations. The program analyzed manually defined criteria, and of the 82 countries, 40 reached the previously defined threshold. For each of the 82 countries, the total strength of the co-authorship link with other countries was also calculated. The maximum number of connected and forming groups was 40, 4 clusters were constituted with 603 cooperation links with a total link force of 2383.

Figure 6 shows the network of co-authors between Latin American countries with countries of other regions. It can be observed, according to the size of the nodes, that Brazil is the country with the highest number of articles and co-authorship. The vast majority of her co-authorship is established with European countries (France, Germany, Denmark, Ireland, Portugal, Austria), Asians (China), and in America (Uruguay). It is followed by Mexico, Chile, Argentina, and Colombia, with a total liaison force of 130, 120, 111, and 67. These countries in the figure constitute cluster number 4 in yellow. For their part, Venezuela, Costa Rica, Uruguay, Ecuador, and Peru are the Latin American countries with the least number of relationships from other regions.

Figure 6. *Co-authorship between LAC countries with the rest of the world and LAC with each other on the bioeconomy issue*



Finally, the graph shows good relationships established between the countries, in terms of co-authorship, given that when analyzing the connecting lines, most are of the same thickness. Additionally, the countries are currently strengthening their policies for the development of the bioeconomy.

Co-authorship analysis based on the institutions that publish on the subject of bioeconomy

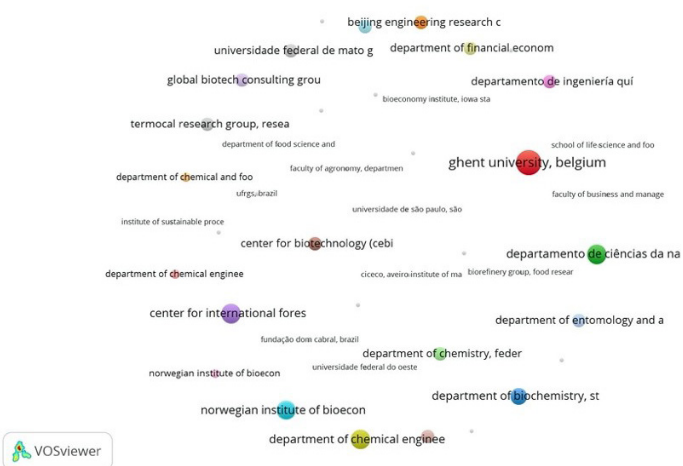
Scientific collaboration between institutions refers to any process involving the work of several individuals to achieve a common goal. The increase in scientific collaboration has several causes, among them are complex difficulties whose solution requires an inter and multidisciplinary approach, financing policies that stimulate the formation of working groups, regional cooperation agreements; and information technologies that facilitate remote work. Table 6 shows the network of co-authorship relationships between institutions on the subject of bioeconomy at the LAC level. The Universities of Ghent University, Belgium; Institute of agricultural and fisheries research (ilvo), Belgium; Ithaka institute for carbon strategies, arbaz, Switzerland; Nutrient management institute nmi, Netherlands;

They are characterized by presenting the highest total link strength of the ten selected institutions. The link strength is an indicator of connection within the network. Figure 7 shows the network of co-authorship relationships between institutions on the subject of bioeconomy, 2163 organizations were identified, a maximum number of 2 documents per organization, and a minimum number of citations for each organization of 0, with this criterion, 71 organizations were identified. There are no relationships between the institutions, due to the degree of dispersion of the institutions and the information.

Table 6. *Main institutions in co-authorship activities on the subject of bioeconomy*

Main institutions	Documents	Citation s	Total Link Strength
Ghent University,Belguim	2	0	7
Institute Of Agricultural And Fisheries	2	0	7
Ithaka Institute for Carbon Strategies, Arbaz,	2	0	7
Nutrient Management Institute Nmi,	2	0	7
Center for International Forestry Research	2	12	4
Departamento De Ciências Da Natureza,	2	15	4
Departamento De Ciencias Da Natrureza.	2	15	4
Departamento De Química, Universidad	2	15	4
Departamento Of Chemical Engineeting And	2	1	4
Institute of Geography, Soil Science/Soil	2	12	4

Figure 7. *Institutions in co-authorship activities about bioeconomy*



Co-citation / Cited Sources / Fractional Count

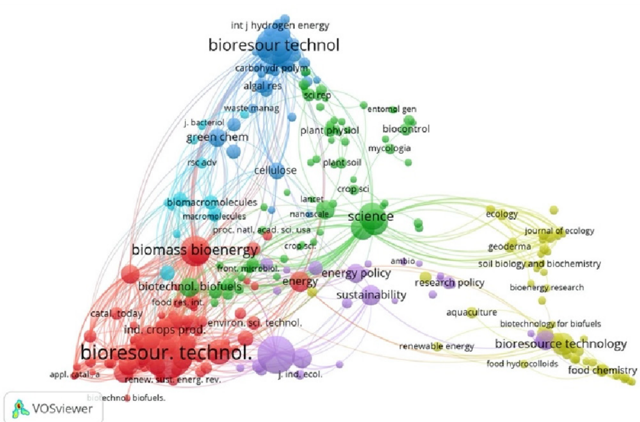
When two sources or authors are cited in the reference list of a document, they form a joint citation or co-citation relationship. The program analyzed the cited sources used in bioeconomy research. This analysis constitutes a potential method to assess any topic's general structural horizon and its related sources. At least 20 citations from a source were selected, identifying 323 out of 18,118 sources that met the established limit. The data were grouped into 6 clusters with a total link strength of 603,189. Table 7 shows the ten principal sources of the bioeconomy with their number of citations and total link strength. It was identified that the journal with the highest number of citations was the journal Bioresourse Technol with several citations of 1071 and a total link strength of 72644. However, this was not the journal with the highest productivity, since as stated in figure 2, the journal with the highest number of articles is the Journal of Cleaner Production.

Table 7. *Top ten sources cited, number of citations, and total link strength*

Sources	Citations	Link
Bioresour. Technol.	1071	strength72644
Bioresour Technol	581	34425
Biomass Bioenergy	370	26963
J. Clean. Prod.	579	19747
Fuel	218	17806
Energy Fuels	153	17377
Plos One	246	16089
Ind. Eng. Chem. Res.	154	15102
Biotechnol. Biofuels	161	14528
Renew. Sustain. Energy Rev.	255	14184

Figure 8 shows the density network of sources cited in the bioeconomy research, sources with a higher binding force are denser than those with a lower binding force. We use the Cocitation type of analysis to emphasize the importance and dominance of the technological factor within the framework of the bioeconomy. As shown in the figure, the essential sources in terms of bioeconomy are related to natural science. Those related to social sciences are less dense (purple cluster), in the lower central part of the density network; This confirms the earlier claim of a technology-oriented bioeconomy.

Figure 8. *Citation density analysis of sources cited in bioeconomy publications*



Keyword concurrency analysis

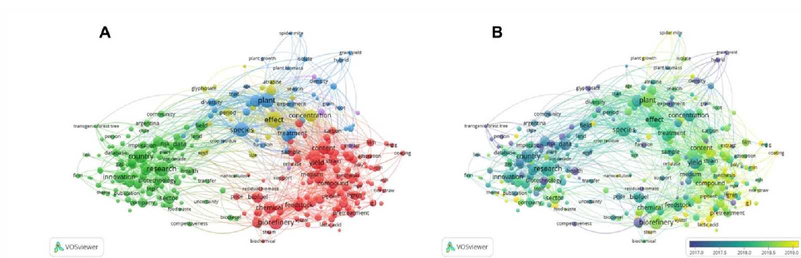
Keyword matching analyzes the research access point in a discipline and studies research trends in a defined domain. To build the bioeconomy scientific literature network, we used the coincidence analysis type, the full count method, and the keywords present in the title and abstract as the analysis unit. A total of 18,566 terms were identified in the database; it was established as a minimum criterion of occurrence of the term, 10 words. When making this selection, 520 terms were identified that met the established limit; Vosviewer suggests an additional selection by evaluating 60% of the most relevant terms, corresponding to 312 words. Table 8 lists the 10 most frequently used keywords in bioeconomy research in LAC. For each of the 312 keywords, the total link strength was calculated; Words were grouped into 5 clusters, cluster 1 with 128 elements, cluster 2 with 118, cluster 3 with 39, cluster 4 with 21, and cluster 5 with 6 constituent elements.

Table 8. *The 10 most common keywords used in bioeconomy research in LAC*

Keywords	Cluster	Occurrence	Total Link Strength
Effect	4	216	3838
Plant	3	189	3292
Research	2	188	3278
Species	3	176	3220
Biorefinery	1	162	2414
Country	2	152	2542
Yields	1	142	2447
Concentration	4	132	2775
Property	1	130	2008
Content	1	129	2247

Concerning the distribution cloud of the topics, two larger groups are constituted in red and green colors. The red cluster mainly groups the terms related to research lines from the biological and chemical sciences. In contrast, the green cluster groups are related mainly to social and political sciences (Figure 9A). In figure 9B, the network map of the trend issues is presented. The appearance of key concepts in the bioeconomy literature is evidenced in recent years, such as lignin, extracts, valorization, lactic acid, and Gay Lussac. This type of term allows us to identify that a trend towards recognizing natural resources as a source of wealth is consolidating.

Figure 9. *Keyword co-occurrence analysis in bioeconomy research. Coverage display*



LAC is a heterogeneous region in terms of R&I systems in agriculture in many aspects, which represent challenges and opportunities given the strengths and capacities of each of them, having an extraordinary diversity of natural resources, but with a very low capacity to appreciate/guard it and take advantage of it. On the other hand, there is awareness throughout the region that it is necessary to have more monetary funds and increase the infrastructure and training of qualified personnel. To consolidate the R&I processes, it is necessary to increase and consolidate the critical mass and develop novel processes/techniques to go beyond just being technology adopters. The entire region must transition towards a bioeconomy strategy that offers the possibility of transcending the dichotomous agriculture/industry vision so widespread in the region.

The emerging bioeconomy provides new options for the creation of quality jobs associated with renewable natural resources, opens opportunities for agriculture beyond food, by implementing new production methods that take advantage of biomass for multiple uses as well as the elaboration of bio-inputs for agriculture and facilitates the creation of knowledge-based startups, inserted in new value chains associated with the use of biomass. However, there are several obstacles that LAC countries must work on to take full advantage of the opportunities offered by the bioeconomy, including i) the lack of adequate regulatory frameworks, especially in areas of the rapid advance of biotechnological applications; ii) disjointed regulatory frameworks and incentive policies; iii) insufficient coordination of existing scientific and technological capacities; iv) restriction of the entry of SMEs into a concentrated biotechnology market; and v) lack of financing for the creation of innovative bioeconomy companies (ECLAC, 2017). In particular, despite the clear competitive advantages of several countries in the region, dedicated bioeconomy strategies have not yet been consolidated, limiting the development of a strategic vision on the bioeconomy and reducing existing initiative's effectiveness.

Additionally, the research volume in the region is relatively low compared to other developed or developing countries, such as China and India. This is reflected in a small number of patents and published articles, and therefore, the capacity for innovation continues to depend on external supplies from developed countries. LAC does not need to be self-sufficient per se, but local technology products must be competitive in the global market. In turn, there is ample potential for intraregional collaboration, such as the Argentine-Brazilian Center for Biotechnology (CABBIO), which promotes interaction between scientific centers and the productive sector of both countries-, the Brazil International Cooperation Program- FAO, which offers technical cooperation in agriculture and food to less developed countries in the region-, or the project "Towards a bioeconomy based on knowledge in LAC in partnership with Europe" within the framework of the Community of Latin American and Caribbean States (CELAC), however, its work has been scarce and disjointed. It is for this reason that the leadership of public agencies, entrepreneurs, and research institutes in countries such as Mexico, Argentina, Brazil, Chile and Colombia can serve to consolidate a regional platform, which helps reduce the gap between the countries of the region and promotes economies of scale, efficient and synergistic. Furthermore, it is of interest to explore the value of the bioeconomy to develop regional value chains, for example, between MERCOSUR and the Pacific Alliance.

4. Conclusions

The bioeconomy in LAC is an ongoing process that, in part, reflects the trend of what is happening in other parts of the world, but, above all, it has comparative advantages and potentialities that suggest strong growth of the same in the region during the next years. It is identified that the transition towards a knowledge-based bioeconomy also depends mostly on the level of applicability of new technology developments in specific sectors of the economy. The expected socio-economic impact can be very high in countries and sectors where value chains are well established, such as Brazil and Argentina. Consequently, for LAC, the knowledge-based bioeconomy will require a significant transformation effort in terms of policies and institutions for its promotion.

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